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IMAGE-PICK UP LENS

BACKGROUND OF THE INVENTION

Technical Field of the Invention

[0001] The present invention relates to an image-pick up lens, which forms an image of an object onto an image-receiving surface.

Related Art

[0002] In recent years, camera modules for taking photos have begun to be incorporated in mobile terminals including mobile phones. Downsizing the camera modules is a prerequisite for these apparatuses in order to enhance their portability. In the meantime, regarding an image pickup device such as CCD and CMOS, a pixel having the size of approximately a few μm has become feasible, and an image pickup device with high-resolution and compact size can be realized. Thus, there is high demand for cost reduction as well as downsizing of an image-pick up optical system to be incorporated to such image pickup device. An optical system is expected to satisfy all requirements of compactness, low cost, high resolution and excellent optical performance, which could conflict with each other.

[0003] More specific requirements expected of the optical system may roughly be classified as follows:

[0004] Low cost (the system including as few lenses as possible; enabled to be formed of resin; and easily assembled)

[0005] Brightness (small F_{no})

[0006] Compactness (particularly, the length from the lens edge to the image pickup device being short)

[0007] Wide angle of field (desirably, 30° or more)

[0008] Uniform illumination on an image surface (few

eclipses/narrowing down the angle of incidence onto an image pickup device)

[0009] High resolution (appropriately corrected fundamental aberrations such as spherical aberration, coma aberration, curvature of field, astigmatism, distortion, and chromatic aberration)

[0010] If an optical system satisfying all the above requirements can be formed with few lenses, the range of applying the system will be broadened. Many kinds of lenses have been proposed so far; however, it has been very difficult to satisfy all the requirements by using only two lenses.

[0011] As for the two-lens structure, arranging "a negative lens and a positive lens" from the side of an object is advantageous in correcting aberrations, but the arrangement limits the size reduction. In order to shorten the overall length of the two-lens structure, it is desirable to arrange a pair of "a positive lens and a positive lens" or a pair of "a positive lens and a negative lens". Moreover, in order to narrow down the angle of incidence onto the image pickup device, it is desirable to employ a 'front-set stop' type, which has an aperture stop at the side closest to the object. Among structures having been proposed so far, Japanese patent unexamined application laid open No. 01-245211 and No. 04-211214 disclose structures satisfying the above requirements.

[0012] Fig. 22 shows a sectional view of the disclosure in the unexamined patent application laid open No. 01-245211. The structure is composed of a first biconvex positive lens and a second negative meniscus lens having a concave surface on the image side. In this example, the second lens exhibits relatively stronger power and has a concave surface on the side of an object, so that the angle of incidence onto the image pickup device is likely to be wide. Consequently, it is difficult to enlarge the angle of field, and the angle of field of the example is approximately 20° , which is a

relatively small value.

[0013] Fig. 23 shows a sectional view of the disclosure in the unexamined patent application laid open No. 04-211214. The structure is composed of an image-pick up lens 10 on the side of an object and a correction lens 20 on the side of an image. In this example, the image-pick up lens 10 on the side of the object takes charge of almost all systems power, and the both surfaces of the correction lens 20 on the side of the image are aspheric. Consequently, field aberration is corrected so as to maintain balance among aberrations that occur when enlarging the angle of field. In this configuration, the lens 10 on the object side is in charge of the fundamental imaging function. Therefore, when the lens on the object side is configured with a single lens, there is a limit in taking balance of field aberrations only by using the correction lens 20 while narrowing down the angle of incidence onto an image pickup device. Moreover, it is also difficult to correct chromatic aberration effectively, and thus widening the angle is limited.

[0014] The present invention provides a low-cost bright image-pick up lens system of a small size which is short in the total length, wherein angle of field is beyond 30° ; the angle of incidence onto an image pickup device can be narrowed down; and various aberrations are appropriately corrected.

SUMMARY

[0015] In order to achieve the above goal, the present invention employs the following configurations. First, according to a first aspect, an image-pick up lens of the present invention comprises, from the side of an object, an aperture stop, a biconvex positive lens and a meniscus lens having a concave surface on the object side. Furthermore, when each lens includes at least one aspheric surface, and 'f' indicates the focal length of all systems,

'f1' indicates the focal length of the positive lens, and 'T' indicates the length from the aperture stop to an image-pick up surface, the following conditions are satisfied:

$$3 < f1/f < 0.9$$

$$T/f < 2.4$$

[0016] According to a second aspect, when both surfaces of at least one of the positive lens and the meniscus lens are aspheric, and regarding the curvature radius of each lens, 'R' indicates the curvature radius of the positive lens on the object side, 'R2' indicates that of the positive lens on the image side, and 'R3' indicates that of the meniscus lens on the object side, the image-pick up lens of the present invention satisfies the following conditions:

$$0 < R2/R1 < 0.5$$

$$0.4 < R3/R2 < 1.0$$

[0017] According to a third aspect, when 'u1' stands for dispersion of the positive lens, and 'u2' for dispersion of the meniscus lens, the image-pick up lens of the present invention satisfies the following conditions:

$$u1 > 50$$

$$u2 < 40$$

[0018] According to a fourth aspect, regarding the image-pick up lens of the present invention, at least one of the positive lens and the meniscus lens is formed of resin material.

[0019] According to a fifth aspect, regarding the image-pick up lens of the present invention, the positive lens and the meniscus lens are joined to each other with a fitting portion which is formed integrally on an external diameter of at least one of the

lenses.

[0020] According to a sixth aspect, regarding the image-pick up lens of the present invention, the meniscus lens also functions as a cover for an image pickup device provided on an image side thereof.

[0021] With the above configurations, a targeted image-pick up lens can be provided.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] Fig. 1 is a sectional view of an embodiment of the image-pick up lens.

[0023] Fig. 2 shows an optical section of the Example 1.

[0024] Fig. 3 shows field aberrations of the Example 1.

[0025] Fig. 4 shows an optical section of the Example 2.

[0026] Fig. 5 shows field aberrations of the Example 2.

[0027] Fig. 6 shows an optical section of the Example 3.

[0028] Fig. 7 shows field aberrations of the Example 3.

[0029] Fig. 8 shows an optical section of the Example 4.

[0030] Fig. 9 shows field aberrations of the Example 4.

[0031] Fig. 10 shows an optical section of the Example 5.

[0032] Fig. 11 shows field aberrations of the Example 5.

[0033] Fig. 12 shows an optical section of the Example 6.

[0034] Fig. 13 shows field aberrations of the Example 6.

[0035] Fig. 14 shows an optical section of the Example 7.

[0036] Fig. 15 shows field aberrations of the Example 7.

[0037] Fig. 16 shows an optical section of the Example 8.

[0038] Fig. 17 shows field aberrations of the Example 8.

[0039] Fig. 18 shows an optical section of the Example 9.

[0040] Fig. 19 shows field aberrations of the Example 9.

[0041] Fig. 20 shows an optical section of the Example 10.

[0042] Fig. 21 shows field aberrations of the Example 10.

[0043] Fig. 22 is a sectional view of the disclosure in the

unexamined patent application laid open No. 01-245211.

[0044] Fig. 23 is a sectional view of the disclosure in the unexamined patent application laid open No. 04-211214.

DETAILED DESCRIPTION

[0045] An embodiment of the present invention will be explained based on particular examples of configurations.

[0046] Fig. 1 is a sectional view of an image-pick up lens of the present invention. Light beams incident from the side of an object sequentially pass through an aperture stop 1 at the side closest to the object, a biconvex positive lens 2, and a meniscus lens 3 having a concave surface on the object side so as to be converged on a light receiving surface of an image pickup device 5. Usually, a cover glass is provided between the meniscus lens 3 and the image pickup device 5.

[0047] First, arranging the aperture stop 1 at the side closest to the object is a condition for narrowing down the angle of incidence onto the image pickup device 5. Moreover, in order to shorten the total length of the lenses, it is a basic requirement for the biconvex lens 2 on the object side to satisfy:

$$0.3 < f_1/f < 0.9$$

[0048] The surfaces of the lenses are aspheric appropriately, which is a prerequisite for satisfying many of the required conditions by using the small number of lenses.

[0049] In addition, the biconvex lens 2 on the object side preferably satisfies a condition:

$$0 < R_2/R_1 < 0.5$$

[0050] This condition is for narrowing down the angle of incidence onto the image pickup device 5 along with the condition of the front-set stop. When a value of the condition is below the lower limit, 'R2' becomes relatively small, so that various aberrations generated at the surface become too appreciable to be

corrected with ease. On the other hand, when a value of the condition is more than the upper limit, 'R2' increases, and the power at the biconvex lens 2 on the image side becomes small. Consequently, it is necessary to place the aperture stop 1 further away in order to narrow down the angle of incidence onto the image pickup device 5. Accordingly, field aberrations due to the biconvex lens 2 get too appreciable to be corrected with ease. Moreover, the total length 'T' including the aperture stop 1 is long.

[0051] Regarding the meniscus lens 3 having a concave surface on the object side of the image side, the paraxial focal length can be negative or positive; however, it is desirable to satisfy the following condition:

$$0.4 < R3/R2 < 1.0$$

[0052] This condition is for keeping the aberrations in satisfactory conditions along with the above condition regarding 'R1' and 'R2'. If a value of the condition is beyond the upper limit and/or below the lower limit, balance with 'R2' having relatively strong power collapses. Consequently, it is difficult to keep the aberrations of image height in satisfactory conditions.

[0053] Also, in order to appropriately correct a chromatic aberration, dispersion 'u1' of the biconvex lens 1 and dispersion 'u2' of the meniscus lens preferably satisfy the following conditions:

$$u1 > 50$$

$$u2 < 40$$

[0054] The fundamental constituent elements of the present invention are as explained above. Next, attendant circumstances for providing a low-cost image-pick up lens of a small size are explained. First, it is preferable to employ resin as the material for the lenses in order to improve efficiency in assembling while reducing as much cost and many members used as possible. Various ideas have been presented as to the integration of the

image pickup device 5 and the optical system in particular. However, there are few specific suggestions including those for the lens structure, and implementation is difficult in many cases.

[0055] In the present invention, the primary structure is an arrangement of "a positive lens and a positive lens" or of "a positive lens and a negative lens". Accordingly, the meniscus lens 3 and the image pickup device 5 are closely located and can easily be integrated. Moreover, when a structure is added for fitting a convex lens to the external diameter of the meniscus lens 3 on the object side, the meniscus lens 3 having a concave surface on the object side can incorporate the fitting structure as a lens-shaped natural extension thereof. Therefore, the performance is hardly affected. Also, directly fitting lenses to each other is greatly advantageous in that it is possible to maintain precision in respect of de-centering or center deviation and spacing.

[0056] Also, it is cost effective to employ the meniscus lens 3 close to the image pickup device 5 as the cover glass for the image pickup device 5. In that case, the image-pick up lens does not comprise the above-mentioned integral structure from the beginning, and only the meniscus lens 3 is mounted as a substitute for the cover glass, and the biconvex lens 1 can be fitted in a later process.

[0057] Example

[0058] The following illustrates an example of the present invention with specific numerical values.

[0059] Table 1

Lens Constituent Parameter								
Curvature Radius			Space		Refraction		Dispersion	
Example 1			d0	0.130				
1	R1	2.511	d1	1.282	n1	1.492	u1	57.4
2	R2	-0.336	d2	0.091	n2	1.000	u2	
3	R3	-0.260	d3	0.806	n3	1.585	u3	29.9
4	R4	-0.702	d4	1.585	n4	1.000	u4	
Example 2			d0	0.358				
1	R1	1.984	d1	1.630	n1	1.492	u1	57.4
2	R2	-0.486	d2	0.176	n2	1.000	u2	
3	R3	-0.379	d3	0.750	n3	1.492	u3	57.4
4	R4	-1.017	d4	0.091	n4	1.000	u4	
5	R5		d5	0.500	n5	1.492	u5	57.4
6	R6		d6	0.500	n6	1.000	u6	
Example 3			d0					
1	R1	3.421	d1	1.051	n1	1.492	u1	57.4
2	R2	-1.512	d2	0.186	n2	1.000	u2	
3	R3	-0.753	d3	0.955	n3	1.492	u3	57.4
4	R4	-0.914	d4	2.308	n4	1.000	u4	
Example 4			d0	0.714				
1	R1	2.053	d1	1.707	n1	1.492	u1	57.4
2	R2	-0.553	d2	0.274	n2	1.000	u2	

3	R3	-0.408	d3	1.100	n3	1.585	u3	29.9
4	R4	-0.704	d4	0.705	n4	1.000	u4	
Example 5			d0	0.663				
1	R1	2.223	d1	1.506	n1	1.492	u1	57.4
2	R2	-0.843	d2	0.622	n2	1.000	u2	
3	R3	-0.496	d3	0.783	n3	1.585	u3	29.9
4	R4	-0.619	d4	0.468	n4	1.000	u4	

[0060] Table 1 is a list showing configurations of the examples 1 through 5. The numbers on the left edge of the table correspond to the respective surfaces of the lenses. 1 indicates the first surface of the biconvex lens 2; 2 indicates the second surface of the lens 2; 3 indicates the first surface of the meniscus lens 3; and 4 indicates the second surface of the lens 3. 5 or 6, if any, indicates the cover glass. Moreover, R stands for curvature radius; d for space; n for refraction; and u for dispersion.

[0061] Table 2 is a list showing aspheric coefficients of the same examples 1 through 5. The aspheric surface of the present invention employs the one shown by the first formula for convenience; however, it is not limited to this type.

[0062] Formula 1

$$z = \frac{ch^2}{1 + \sqrt{1 - (1+k)c^2h^2}} + A_4h^4 + A_6h^6 + A_8h^8 + \dots + A_{26}h^{26}$$

[0063] Here, 'z' in the formula 1 indicates the depth from the reference surface in the direction of an optical axis passing through the apex of the aspheric surface. Also, 'c' is the inverse

number of the curvature radius R of the surface, and 'h' indicates the height from the optical axis of the surface. 'k' is a conic constant, and A_4 to A_{26} are correction coefficients of the aspheric surfaces.

[0064] Table 2

Coefficients of Aspheric Surfaces					
	Conic Constant	A 4	A 6	A 8	A 10
Example 1					
1	-13.451				
2	-2.040	2.35406E-02	-5.19505E-02	1.54612E-01	
3	-1.730	-1.69190E-02	2.18298E-01	-1.28042E-02	
4	-1.720	-2.60747E-02	6.16902E-02	-1.56946E-02	
Example 2					
1	-11.619				
2	-2.038	-3.11096E-01	2.33868E-01	4.40133E-02	
3	-1.604	-3.12122E-01	7.27748E-01	-2.42919E-01	
4	-1.592	-1.00454E-01	1.87369E-01	-2.60557E-02	
5					
6					
Example 3					
1	0.069	1.79998E-02	-1.61635E-01	2.43031E-01	
2	3.430	1.96991E-03	1.97232E-01	-5.48315E-01	
3					
4	-0.962	-3.65765E-02	7.43552E-03	-4.65821E-02	5.35606E-02
Example 4					
1	-11.361	8.67725E-02	-4.87762E-02		
2	-1.980	1.23464E-02	-1.17956E-02	-1.13937E-02	
3	-1.624	-1.59901E-02	1.75411E-02	-6.24389E-04	
4	-1.397	9.98882E-03	5.08110E-03	3.37427E-03	
Example 5					

1	-10.230				
2	-1.795	-7.56406E-03	-1.00641E-01	7.54959E-02	
3	-1.244	1.70940E-02	2.65075E-01	-8.58190E-02	
4	-1.418	-3.20681E-02	9.94592E-02	2.11404E-03	

[0065] Similarly, table 3 is a list showing constituent parameters of Examples 6 through 10 of the present invention.

[0066] Table 3

	Radius Curvature		Spacing		Refraction		Dispersion	
Example 6			d0	0.213				
1	R1	1.926	d1	1.730	n1	1.492	u1	57.4
2	R2	-0.645	d2	0.442	n2	1.000	u2	
3	R3	-0.370	d3	0.862	n3	1.585	u3	29.9
4	R4	-0.526	d4	0.445	n4	1.000	u4	
Example 7			d0	0.555				
1	R1	1.878	d1	1.712	n1	1.492	u1	57.4
2	<u>R2</u>	-0.598	d2	0.266	n2	1.000	u2	
3	R3	-0.380	d3	0.750	n3	1.585	u3	29.9
4	R4	-0.653	d4	0.117	n4	1.000	u4	
5	<u>R5</u>		d5	0.500	n5	1.492	u5	57.4
6	R6		d6	0.400	n6		u6	
Example 8			d0	0.323				
1	R1	2.658	d1	2.204	n1	1.492	u1	57.4
2	<u>R2</u>	-0.720	d2	0.285	n2	1.000	u2	

3	R3	-0.434	d3	0.750	n3	1.585	u3	29.9
4	R4	-0.789	d4	0.738	n4	1.000	u4	
5	R5		d5	0.500	n5	1.492	u5	57.4
6	R6		d6	0.400	n6		u6	
Example 9			d0	0.382				
1	R1	4.705	d1	1.318	n1	1.694	u1	53.2
2	R2	-0.754	d2	0.210	n2	1.000	u2	
3	R3	-0.395	d3	0.771	n3	1.585	u3	29.9
4	R4	-0.769	d4	1.420	n4	1.000	u4	
Example 10			d0	0.080				
1	R1	2.921	d1	1.204	n1	1.492	u1	57.4
2	R2	-0.881	d2	0.150	n2	1.000	u2	
3	R3	-0.542	d3	0.775	n3	1.585	u3	29.9
4	R4	-0.899	d4	2.270	n4	1.000	u4	

[0067] Table 4 is a list showing coefficients of aspheric surfaces corresponding to the Examples 6 through 10 of the table 3.

[0068] Table 4

	Conic Constant	A 4	A 6	A 8	A 10
Example 6					
1	-7.369				
2	-1.782	-1.04658E-02	-1.03146E-01	4.12922E-02	

3	-1.382	2.42883E-03	2.79388E-02	5.51694E-02	
		-8.63345E-			
4	-1.723	02	6.47178E-02	1.41343E-02	
Example 7					
1	-2.701				
		-7.60304E-	-7.63954E-		
2	-2.204	03	02	7.36559E-02	
		-9.72389E-			
3	-1.613	02	1.91092E-01	-2.73574E-02	
4	-1.388	6.03458E-03	4.73632E-02	6.35925E-03	
5					
6					
Example 8					
1					
2	-4.079				
		-1.72299E-			
3	-2.328	01	1.27672E-01	-6.42517E-02	
		-7.76963E-			
4	-1.286	02	1.70223E-01	-7.17392E-02	
		-3.68424E-			
5	-1.223	02	5.54292E-02	-7.03725E-03	
6					
Example 9					
1		-2.76155E-	-2.56448E-		
		02	01		
		-1.04159E-	-1.54110E-		
2	-2.155	01	01	1.37588E-01	
3	-1.580	3.60074E-02	1.09120E-03	1.17720E-01	
4	-1.935	7.60423E-03	1.06919E-01	-2.55589E-02	
Example 10					
1	-12.554	-1.97026E-	3.33365E-01		

		02		1.12935E+00	
2					
		-1.58105E-			
3	-0.846	01	3.06970E-01		
		-2.51383E-			1.89989E-
4	-1.035	02	5.25718E-02	3.68552E-03	02

[0069] In each of the Examples 2, 7 and 8 of the above Examples, the image-pick up lens includes the cover glass on the image side thereof.

[0070] Table 5 is a list showing the relationship between focal lengths and parameters regarding the Examples 1 through 10. In the table, the height of principal ray H2 indicates the height of passage of the principal ray corresponding to the maximum angle of field at the surface of the positive lens 2 on the image side. Similarly, H3 indicates such height at the surface of the meniscus lens 3 on the object side. Also, a surface angle means a tangential angle at a surface at a point where the above principal ray passes through.

[0071] Table 5

Example	1	2	3	4	5	6	7	8	9	10
Fno	2.80	2.94	2.92	2.87	2.92	2.86	2.18	2.84	2.78	2.93
Angle of Incidence	32.00	32.00	26.00	32.00	32.00	32.00	32.00	32.00	32.00	26.00
Angle of Emitting	14.73	16.17	13.71	4.96	13.51	15.47	11.23	14.00	14.00	14.05
Focal Length										
f	2.04	2.12	2.65	2.06	2.11	2.06	2.05	2.69	2.04	2.63
f1	0.70	1.01	2.28	1.13	1.48	1.26	1.19	1.46	1.03	1.53
f2	-2.17	-2.00	8.99	4.32	3.09	2.00	78.69	-7.58	-5.83	-11.88

f1/f	0.35	0.48	0.86	0.55	0.70	0.61	0.58	0.54	0.51	0.58
Total Length										
T	3.89	4.00	4.50	4.50	4.04	3.69	4.30	5.20	4.10	4.48
T/f	1.91	1.89	1.70	2.18	1.91	1.80	2.10	1.94	2.01	1.70
R2/R1	0.13	0.24	0.44	0.27	0.38	0.33	0.32	0.27	0.16	0.30
R3/R2	0.77	0.78	0.50	0.74	0.59	0.57	0.64	0.60	0.52	0.61
Height of Principal Ray H2	0.46	0.65	0.31	0.82	0.78	0.64	0.75	0.82	0.58	0.38
Height of Principal Ray H3	0.47	0.65	0.36	0.82	0.82	0.67	0.76	0.83	0.58	0.40
H3/H2	1.01	1.01	1.14	1.00	1.05	1.06	1.01	1.01	1.01	1.05
Surface Angle ϕ_2	38.34	43.58	12.77	40.56	38.57	38.92	38.01	42.52	35.26	25.31
Surface Angle ϕ_3	43.81	43.76	28.32	46.91	39.54	49.14	44.66	51.73	42.93	38.07
$\Phi_2/3$	0.88	1.00	0.45	0.86	0.98	0.79	0.85	0.82	0.82	0.66

[0072] The present invention realizes a low-cost image-pick up lens system of a small size, which is short in the total length, wherein the angle of field is beyond 30°, and the angle of incidence onto the image pickup device is small.

[0073] The entire disclosure of Japanese Patent Application No. 2002-136254 filed May 10, 2002 is incorporated by reference.

CLAIMS

What is claimed is:

1. An image-pick up lens comprising:
 from a side of an object:
 an aperture stop;
 a biconvex positive lens; and
 a meniscus lens having a concave surface on the object side,
 wherein, when each of the lenses has at least one aspheric
 surface; and 'f' indicates a focal length of all systems, 'f1' indicates
 a focal length of the positive lens, and 'T' indicates a length from
 the aperture stop to an image-pick up surface:

$$0.3 < f1/f < 0.9 \text{ and } T/f < 2.4.$$

2. The image-pick up lens according to Claim 1, wherein, when
 at least one of the positive lens and the meniscus lens is aspheric
 on both surfaces and R1 indicates a curvature radius of the
 positive lens on the object side, R2 indicates a curvature radius of
 the positive lens on a side of an image, and R3 indicates a
 curvature radius of the meniscus lens on the object side:

$$0 < R2/R1 < 0.5 \text{ and } 0.4 < R3/R2 < 1.0.$$

3. The image-pick up lens according to Claim 1, wherein, when
 u1 stands for dispersion of the positive lens, and u2 for dispersion
 of the meniscus lens:

$$u1 > 50 \text{ and } u2 < 40.$$

4. The image-pick up lens according to Claim 1, wherein at
 least one of the positive lens and the meniscus lens is formed of
 resin material.

5. The image-pick up lens according to Claim 4, wherein the positive lens and the meniscus lens are joined to each other with a fitting portion which is formed integrally on an external diameter of at least one of the lenses.

6. The image-pick up lens according to Claim 1, wherein the meniscus lens also functions as a cover for an image pickup device provided on a side of an image thereof.

ABSTRACT

A low-cost bright image-pick up lens of a small size is provided which is short in total length, wherein the angle of field is beyond 30° ; the angle of incidence onto the image pickup device is narrowed; and various aberrations are appropriately corrected. The image-pick up lens comprises, from the side of an object, an aperture stop, a biconvex positive lens, and a meniscus lens having a concave surface on the object side, and each of the lenses includes at least one aspheric surface.

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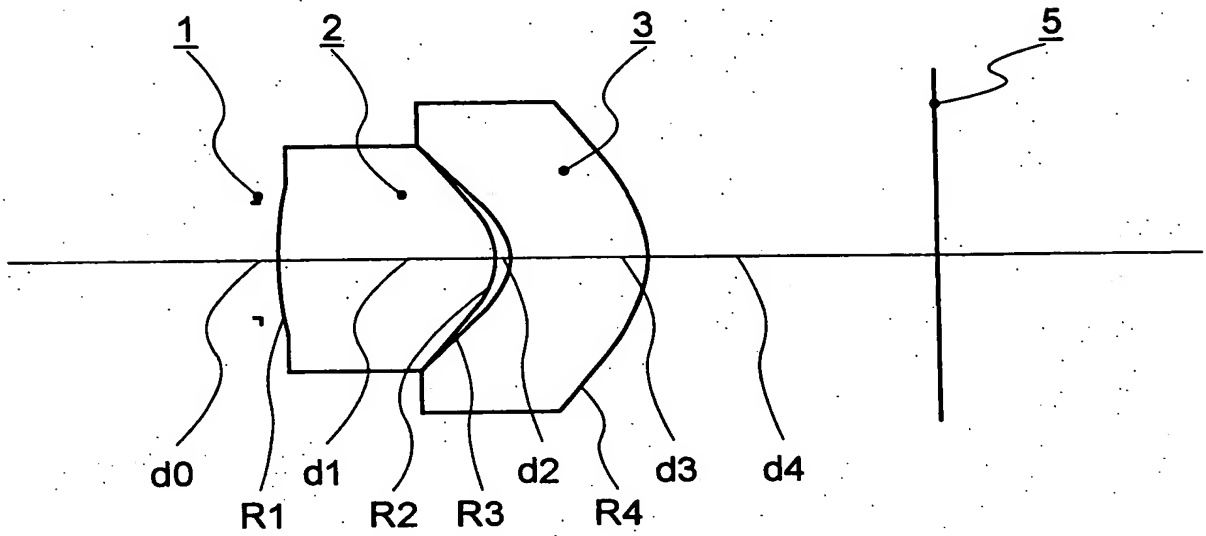


FIG. 1

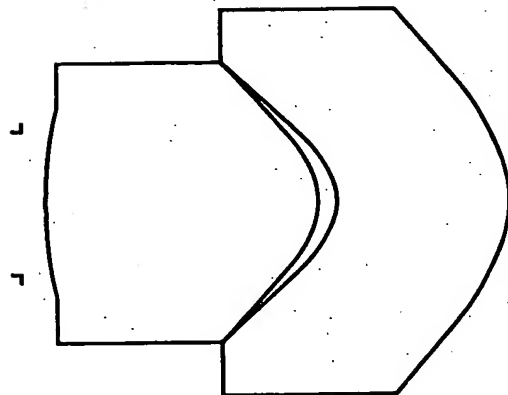


FIG. 2

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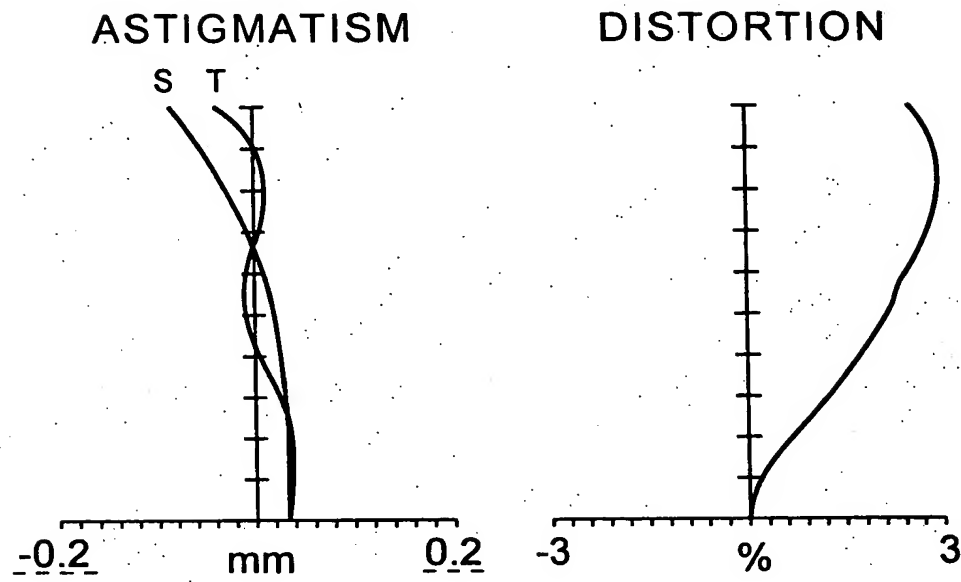


FIG. 3

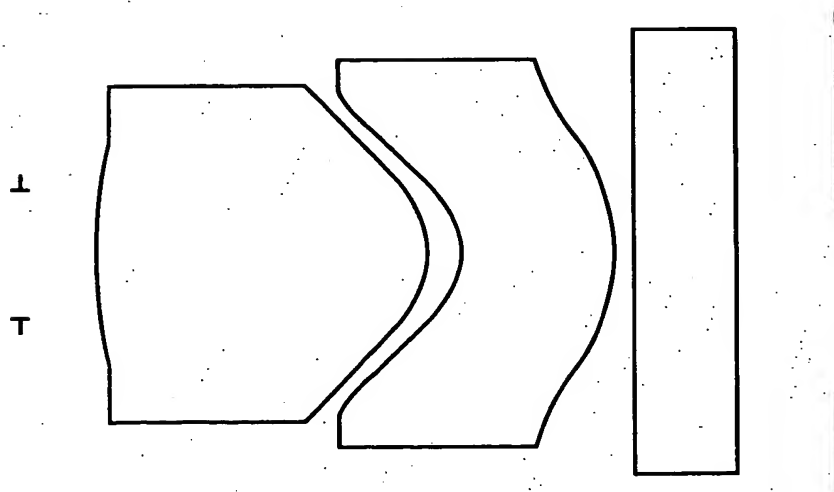


FIG. 4

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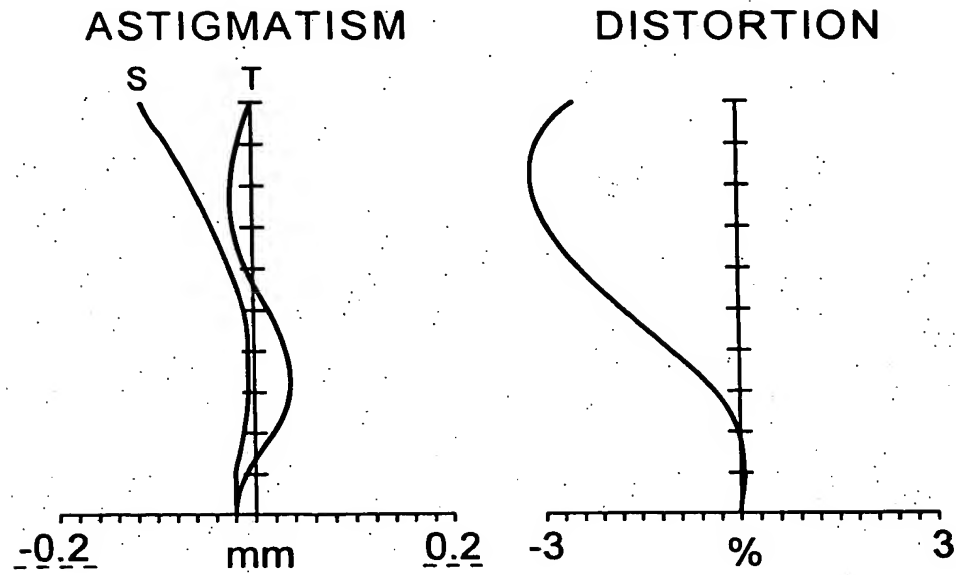


FIG. 5

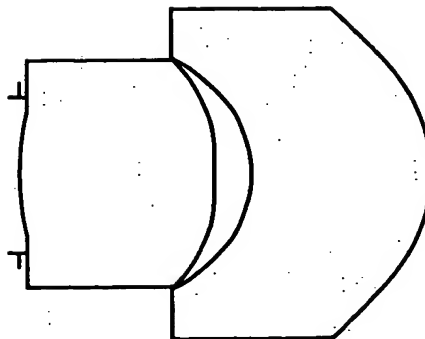


FIG. 6

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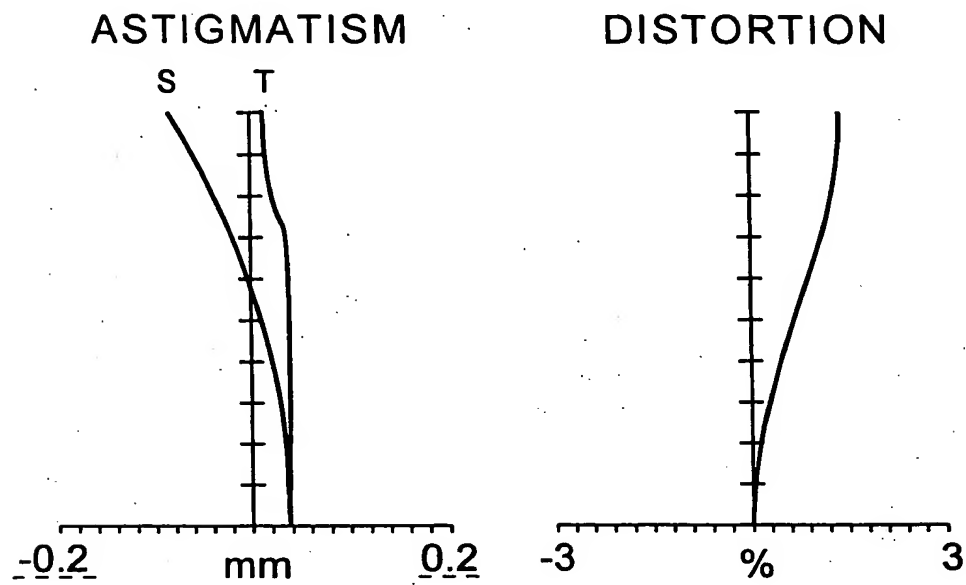


FIG. 7

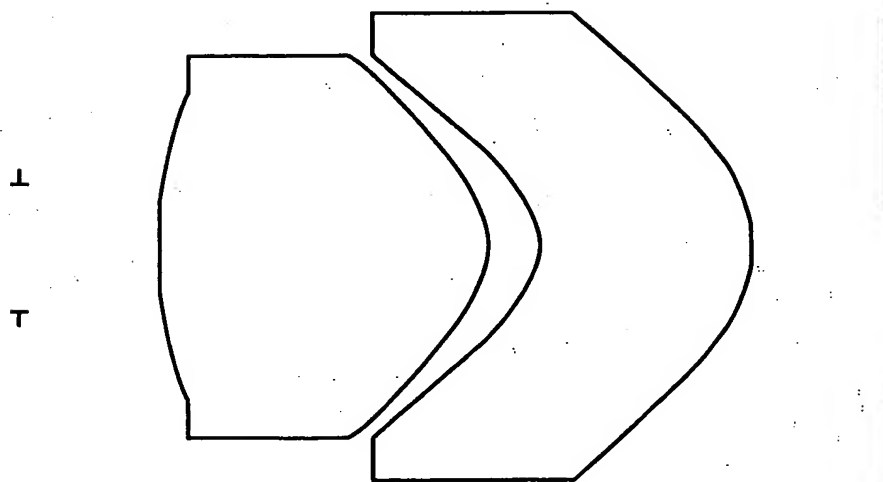


FIG. 8

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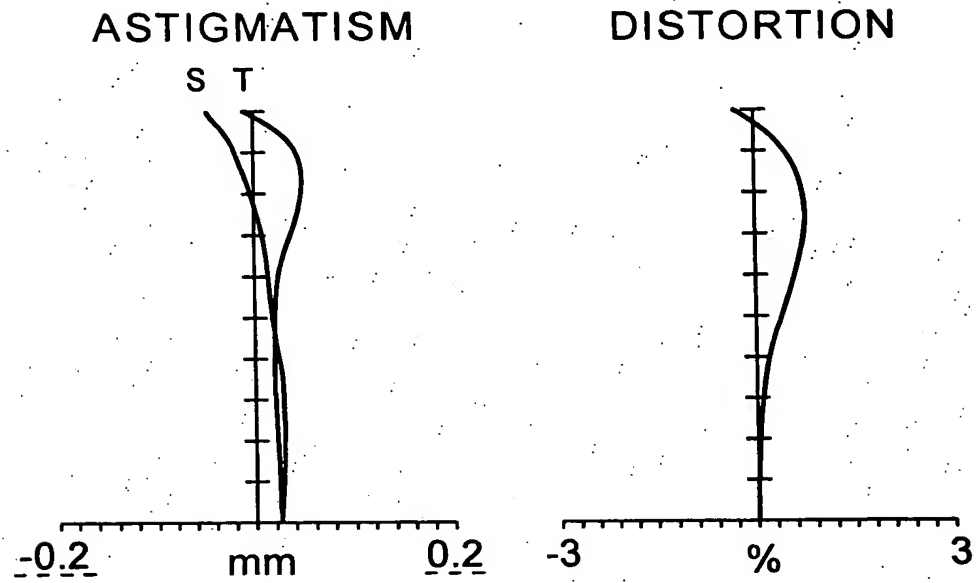


FIG. 9

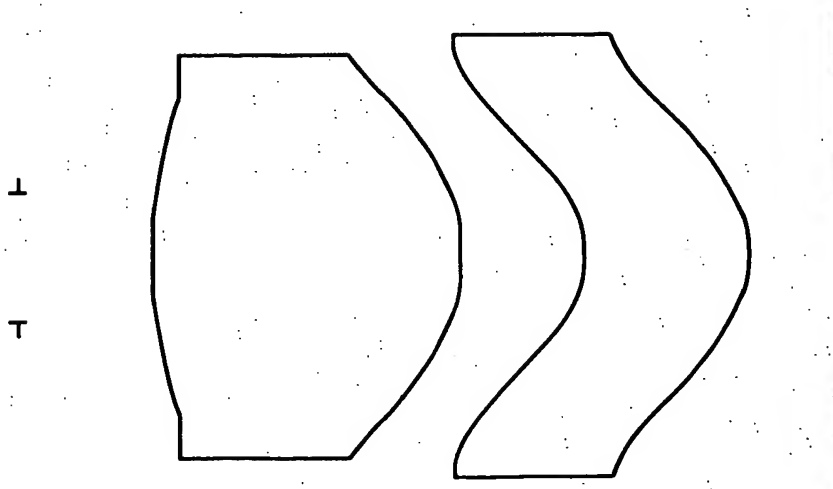


FIG. 10

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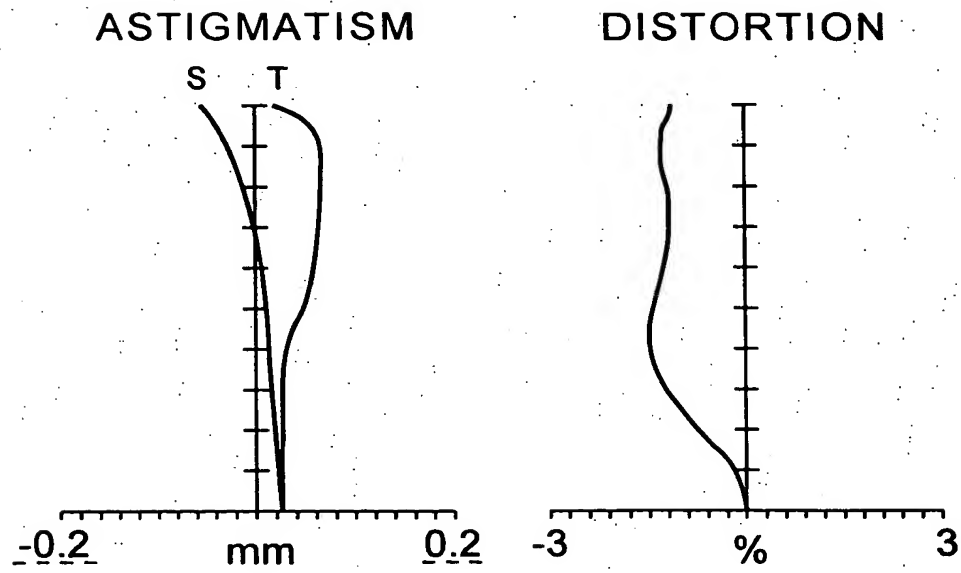


FIG. 11

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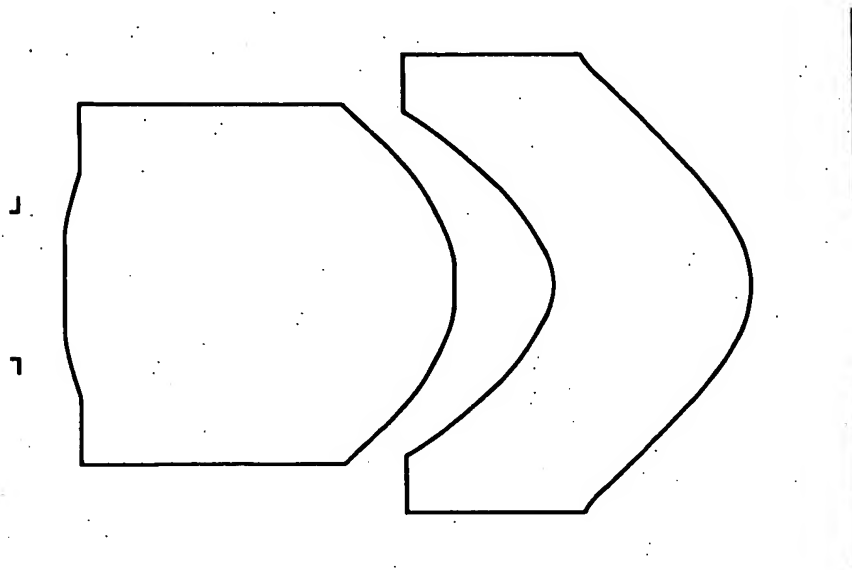


FIG. 12

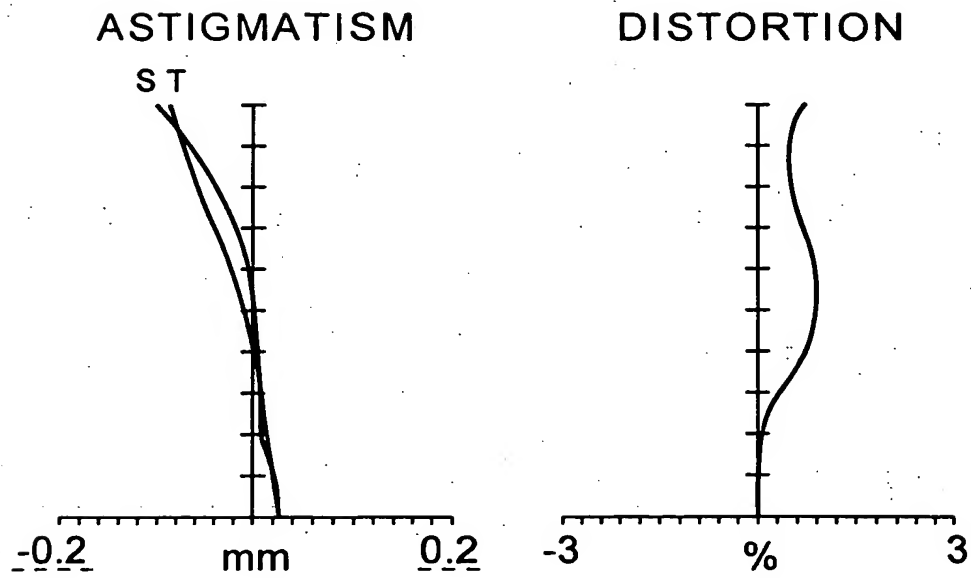


FIG. 13

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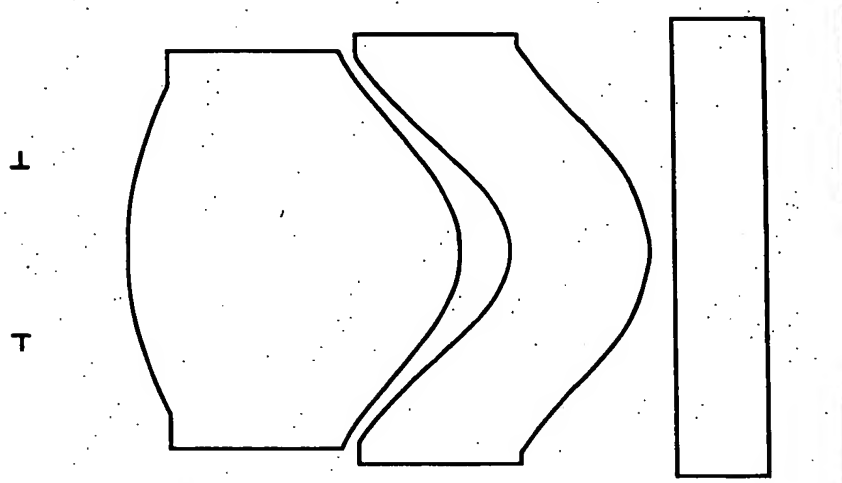


FIG. 14

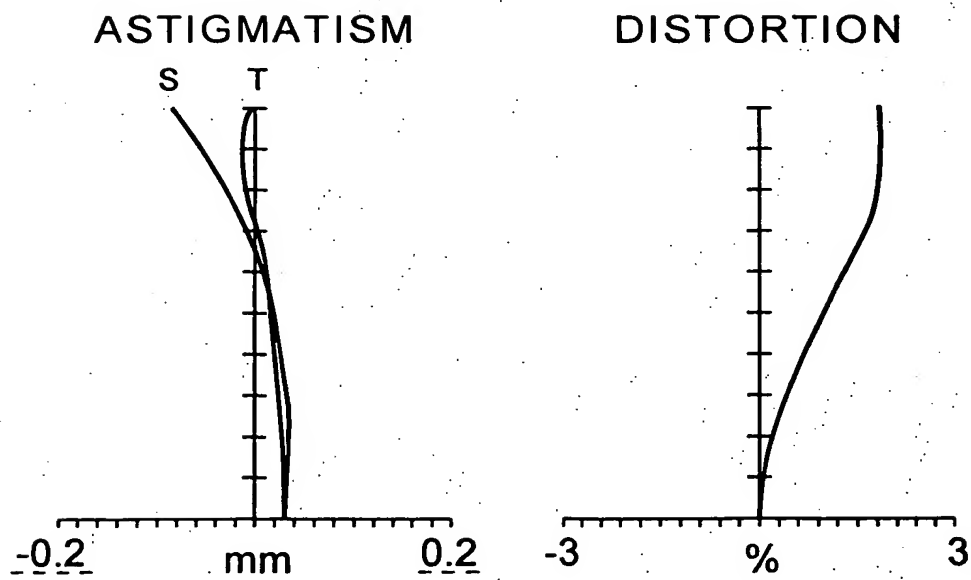


FIG. 15

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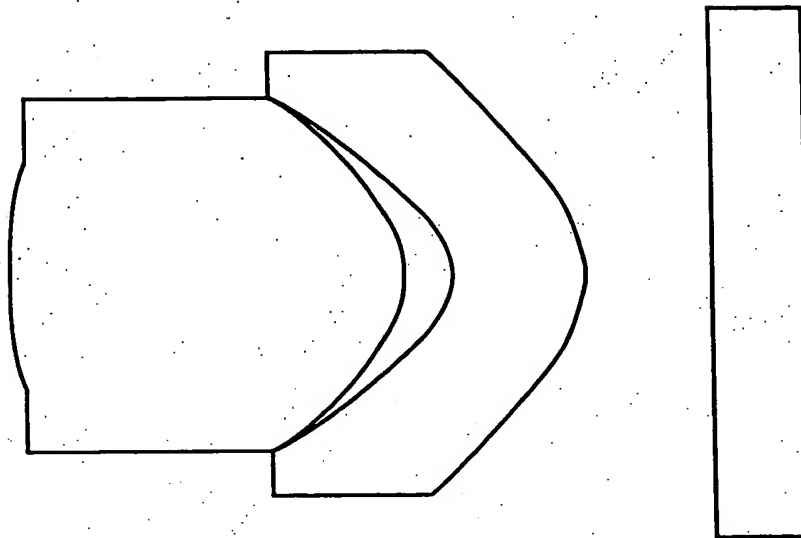


FIG. 16

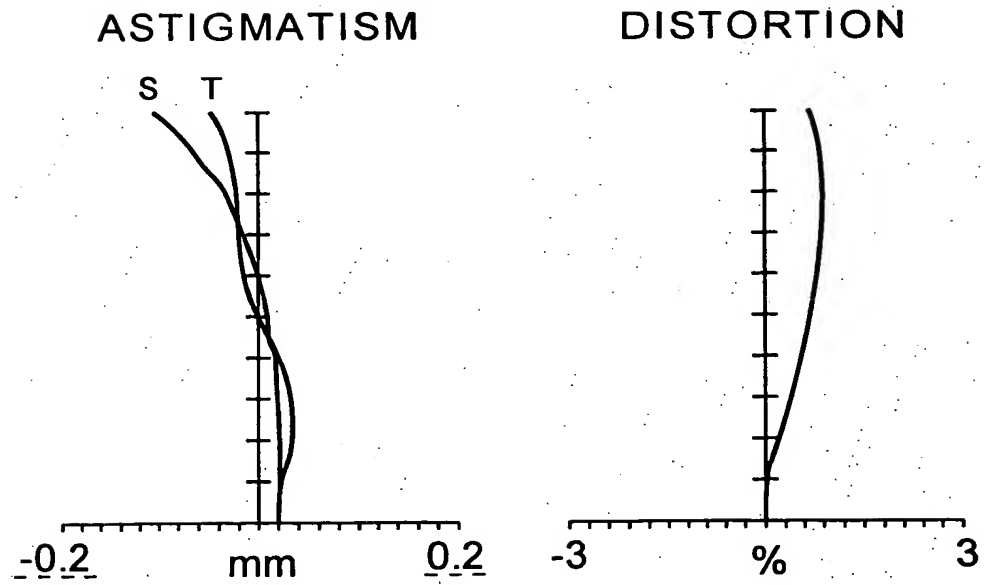


FIG. 17

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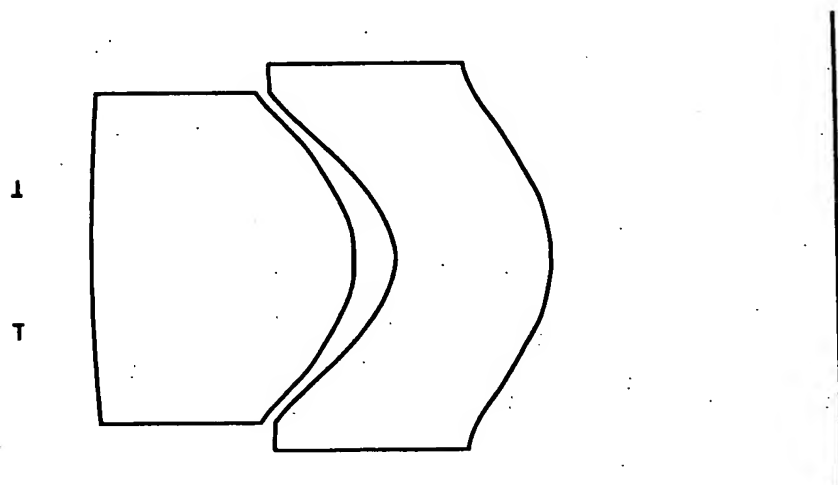


FIG. 18

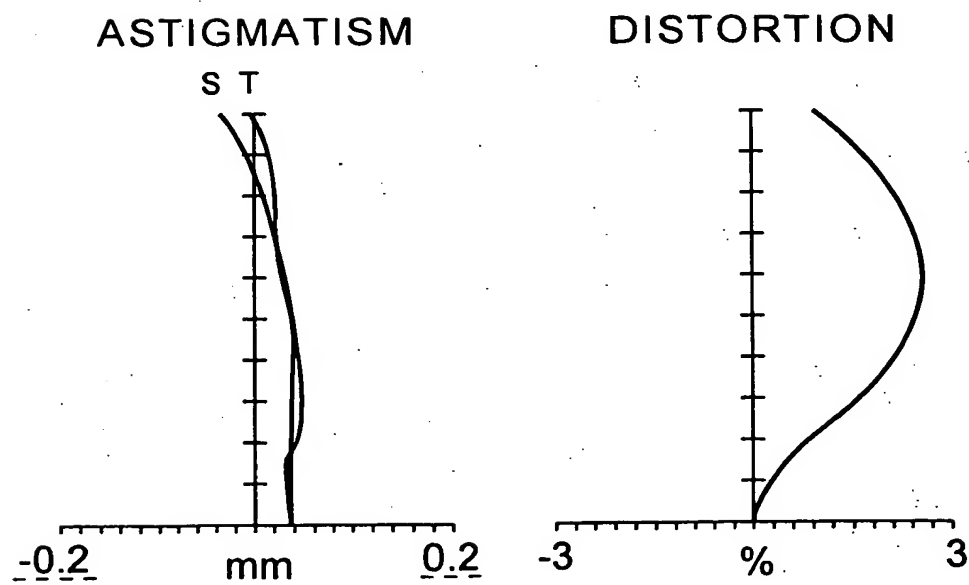


FIG. 19

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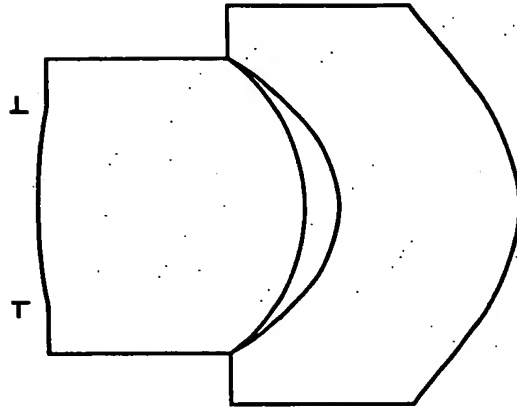


FIG. 20

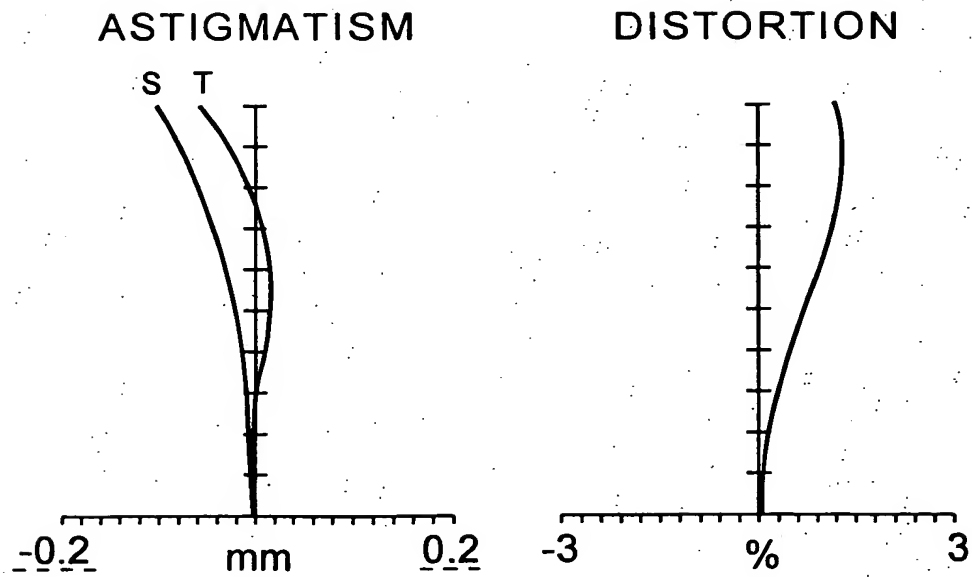


FIG. 21

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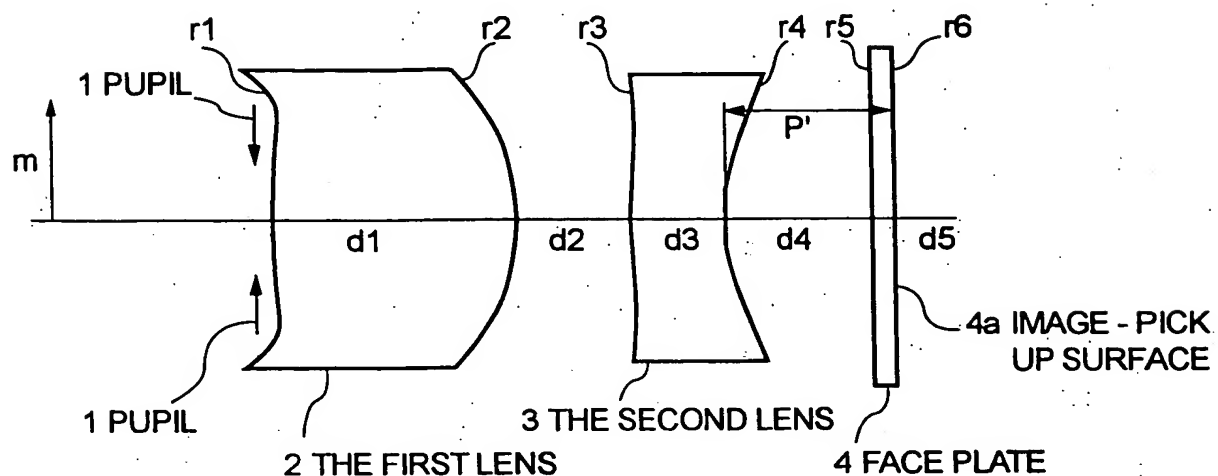


FIGURE OF LENSE CONSTITUTION

FIG. 22

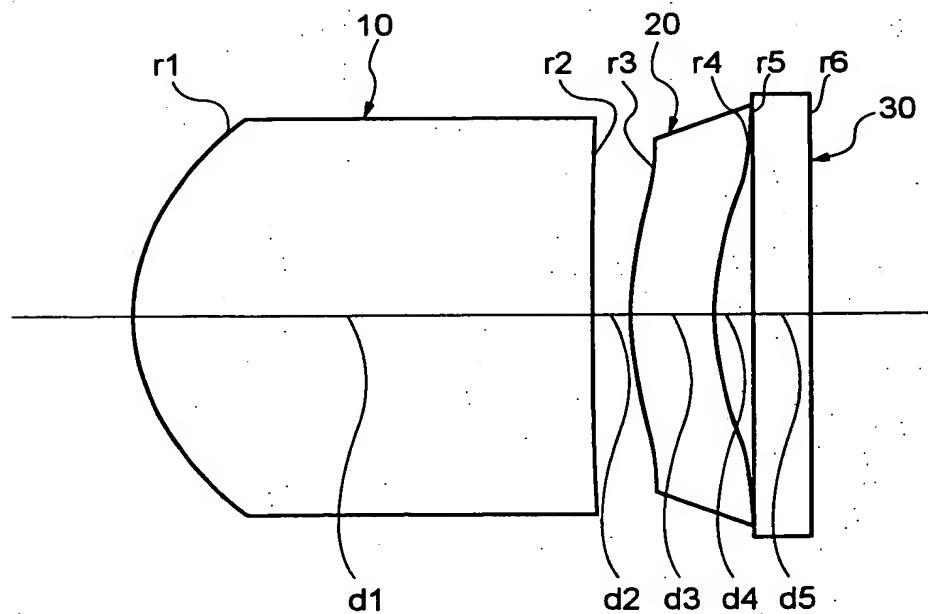


FIG. 23